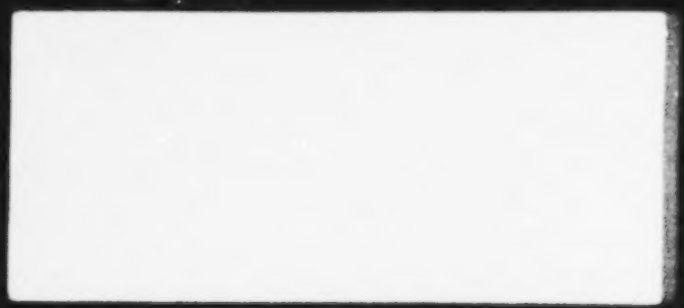
Final Report



A project under the Canada
New Brunswick Conservation
and Renewable Energy
Demonstration Program

PASSIVE SOLAR ADDITION
ADELINE MISENER

Fredericton, N.B.

C.R.E.D.A. Project 101

Canada/New Brunswick Conservation and Renewable Energy Demonstration Program

The Conservation and Renewable Energy Demonstration Program Program is administered in New Brunswick by the Energy Secretariat and managed jointly with Energy, Mines and Resources Canada. The Program is designed to help demonstrate promising conservation and renewable energy technologies, to develop public awareness and understanding of these technologies, and to create employment in new or existing industries.

Through over 100 demonstration projects in New Brunswick, a wide variety of conservation and renewable energy technologies have proven to be technically sound and economically attractive. These demonstration projects should now provide a catalyst for commercialization and lead to widespread adoption of many of these proven technologies.

This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

Conservation & Renewable
Energy Division
Energy Secretariat
P.O. Box 6000
Fredericton, N.B.
E3B 5H1
(506) 453-3897

Programme Canada/Nouveau-Brunswick de démonstration des économies d'énergie et des énergies renouvelables

Le Programme de démonstration des économies d'énergie et des énergies renouvelables est administré au Nouveau-Brunswick par le Secrétariat à l'énergie, en collaboration avec Energie, Mines et Ressources Canada. Ce programme tente d'abord de vérifier la fiabilité des techniques de conservation d'énergie, d'accroître la sensibilité du public envers ces techniques et, enfin, de favoriser la création d'emplois au sein des industries nouvelles ou déjà existantes.

Un grand nombre de projets de démonstration se sont avérés à la fois techniquement réalisables et économiquement attrayants.

Le succès ainsi rencontré encourage la commercialisation des procédés les plus accessibles. Cela entraînerait certes l'adoption d'un grand nombre de ces techniques par les propriétaires de domiciles et par l'industrie privée.

Ce rapport final est basé sur un projet qui a reçu une aide financière du Programme de démonstration. Pour de plus amples renseignements, communiquez avec la:

Division des économies d'énergie
et des énergies renouvelables
Secrétariat à l'énergie
C.P. 6000
Fredericton, N.-B.
E3B 5H1
(506) 453-3897

D I S C L A I M E R

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D E N I D E R E S P O N S A B I L I T E

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SUMMARY

Traditionally, some form of heat storage is associated with passive solar heating. In our design, we used the existing house as the sink for the solar passive addition -- consequently, our entire heating bill for the house was significantly reduced. Supplementary heat was used during overcast days and at night, but we generally kept our temperature lowered during the evening anyway, so heating requirements were minimal.

With triple glazed windows, condensation was not a problem. An effective sealed window curtain was developed which reduced heat loss at night. The roof overhang was effective in restricting incoming summer radiation.

A large window area was found to be very aesthetically pleasing, and the family enjoyed the environment created by the design.

The passive solar addition contributed 36,839,228 BTU's/year to the heating of the entire house. The payback period of the system was determined to be 9.5 years based on the incoming radiation, and 12.8 years based on the difference in electrical heating requirements.

1.0 SOMMAIRE

On a l'habitude d'associer une certaine forme de stockage de la chaleur au chauffage solaire passif. Nous avons conçu un système utilisant la maison elle-même comme aire de diffusion de la chaleur captée par une annexe solaire passive, ce qui a permis de réduire considérablement la facture de chauffage totale pour la maison. Un système d'appoint était utilisé pendant les journées nuageuses et en soirée, mais nous avons l'habitude de baisser la température de toute façon pendant la soirée ce qui fait que nous avions peu besoin de chauffage supplémentaire.

Grâce aux fenêtres à triple vitrage, la condensation n'était pas un problème. Nous avons également installé des rideaux à haut facteur d'isolation pour réduire les pertes de chaleur pendant la nuit. Un surplomb servait en outre à ombrager les fenêtres en été pour réduire les radiations du soleil.

Du point de vue esthétique, l'aire vitrée est très agréable et toute la famille a réagi favorablement au nouveau milieu créé par cette structure.

L'annexe solaire passive a contribué pour 36 839 228 B.t.u./an au système de chauffage de l'ensemble de la maison. Le recouvrement devrait être de 9,5 ans, si on se base sur la chaleur captée, ou de 12,8 ans, si on se base sur la différence en besoins de chauffage électrique.

OBJECTIVES

(i) To develop and demonstrate the application of retro-fit passive solar energy capable of supplying 35 million BTU's.

(ii) To determine the economic feasibility of the above retrofitting of an existing house with passive solar heat.

(iii) To monitor the environment within a house that has been retrofitted with passive solar heat.

(iv) To prepare a technical pamphlet describing the work and results so that it can be applied readily by others.

STUDY JUSTIFICATION

Report ER 79-6 "Passive Solar Heating in Canada", from Energy, Mines and Resources Canada, states all passive solar heating systems are capable of retrofit applications, but there is insufficient data to determine the relative feasibility of alternative passive solar retrofit strategies or the suitability of the existing Canadian building stock for passive solar retrofit. This study attempted to implement and evaluate one such design of passive solar heat retrofit in New Brunswick.

The above report also suggests that, "There is a glaring lack of data concerning the performance of passive solar buildings in the Canadian climate." Yet, it is precisely this type of hard objective information which is required in order to judge the relative merit of passive solar heating. During this study the environment within the house was monitored in order that basic data could be collected upon which design criteria can be formulated. This type of information should lead towards reduced residential heating requirements for the householders of New Brunswick.

This study permitted the applicant to develop and test a design which demonstrated passive solar retrofitting to an exist-

ing home. The design was shown to be economically feasible and aesthetically appealing. The resulting cost effectiveness is given in the report.

FEATURES OF STUDY

(i) Introduction

A functioning passive solar collection system incorporated in an addition was developed which provided heat to the addition and the existing house. No additional thermal storage was added in the design. The percentage of increase in cost due to the solar system represents

$$\frac{5190.70}{12,000 + 5190.70} = 30.2\%$$

The cost of the solar system is shown later in the report.

This represents a higher percentage cost than would be encountered when building a new solar house. There is a much higher collector area to floor area ratio in this addition than there would be in a conventional solar house.

(ii) Technical Description

The existing house is a split-entry, approximately 1,200 sq. ft., located with the rear of the house facing south on the lot designated Figure 1. Three-quarters of the basement is finished with a study, familyroom, bedroom and bathroom. The new addition is 300 sq. ft. -- approximately one-quarter

of the main floor dimension of our existing house. The addition extends from the rear of the house as shown in Figure 2A. It has an insulated crawl space. The passive solar system was incorporated into this new addition. A plan layout of the addition is given in Figure 2B.

The solar system has approximately 180 sq. ft. of south facing glassed area. This represents 12.0% of the above ground floor area of the house. Solar heat gained from the proposed addition is used to heat the entire house on days of bright sunshine. With the above ratio of south facing glassed area to floor area of the house, it was determined that no thermal storage was needed to prevent the house from rising to undesirable temperatures.

Shick and Jones established that south facing glazing should be limited to approximately 10% of the floor area of a well insulated, but otherwise conventionally finished, wood frame building, in order to maintain indoor temperatures within 20 to 26°C and avoid wasteful overheating on clear winter days.

The two rooms were equipped with a ventilation fan (located in the crawl space) and ducting work in order that heated air can be directed to the familyroom and study in the basement of the house as shown in Figure 3. The fan is equipped with a variable speed pulley which controls the speed of the fan as the temperature rises in the solar rooms. Figure 4 gives the construction details of the new addition.

(iii) Monitoring Procedure

Temperatures within the two rooms of the solar addition and the ventilation duct were monitored during a two year period with seven day chart recorders. Relative humidity within the house was measured with a sling psychometer. Air flow within the ventilation system was measured with a Alnor velocity meter.

The effectiveness of the triple glazed windows to transmit solar radiation was determined with a radiometer manufactured by Kipp. A Fluke digital voltmeter was used to measure the output from the radiometer.

Electric heat consumption of the house has been recorded during the past three years.

RESULTS

(i) General

The finished construction is shown in Figure 5. The open window concept was found to be very aesthetically pleasing. One observation noted was the lack of condensation with the triple glazed windows. During the first year double glazing was used and condensation was a severe problem. As a result, the windows were up-graded to triple glazing.

The overhang was found to be effective in restricting incoming radiation during the summer months.

Two pairs of wooden shutters were constructed for a set of windows. Because of the lack of an adequate seal between the shutters and windows, condensation became a problem. However, a second design using a roll-up vinyl blind with a seal proved to be quite effective.

The skylight was found not to be an effective collector because during summer it allowed a great deal of incoming radiation to enter the room. The skylight could not be shaded.

In general, the family has enjoyed the effects created by the design of the solar addition.

(ii) Radiation Transmitted

Results obtained from measuring incoming radiation are presented in the following table. The data were collected on December 21/81 at 1:30 p.m. These data were used in determining the available energy in the new addition when calculating its effectiveness as a heat source.

Radiation Transmitted

Number of Panes of Glass	Radiation (Gm Cal/cm^2). Horizontal Surface	Vertical Surface	% Transmitted Horizontal	% Transmitted Vertical
No glass	4.23	10.45	-	-
1 pane	3.42	8.72	80.9	83.4
2 panes	2.79	6.81	65.9	69.2
3 panes	2.41	5.36	57.0	51.3

(iii) Temperature Profiles

A typical temperature profile for a day with bright sunshine is shown in Figure 6. The temperature in the new addition responded very favourably to bright sunlight. Results from the temperature recorder in the ducting system indicated that the temperature of the air delivered to the main part of the house increased 5 - 12^{o}f on days with bright sunshine. An air flow rate of 500 cfm was found to maintain the temperature in the addition to expected levels during days of bright sunshine.

(iv) Heating Requirements

A comparison of the two heating seasons - 79-80 and 80-81 indicates that the heating requirement for the entire house was significantly reduced with the solar input. This result is even more dramatic when one considers that during the 80-81 heating season, an additional 300 sq. ft. were heated. Figure 7 summarizes the two heating seasons. Similar results were obtained with the 81-82 heating season. The equivalent BTU value of the difference between the 79-80 and 80-81 heating seasons is 10,614,430 BTU's, even though an additional 300 sq. ft. were heated.

INFORMATION TRANSFER

One goal of the project was the preparation of a pamphlet written in both English and French describing the construction of the passive solar heating system, monitoring of the environment achieved by the system and the results obtained from the study. The pamphlet is appended to this report.

Demonstration of the system was undertaken with such groups as the Fredericton Home Economic Association, and Beta Sigma Phi sorority group. Interviews on the CBC radio were also used as an effective tool for information transfer.

Additional information transfer was accomplished by newspaper coverage which are appended to the report. Photographs and construction details were accumulated as the project progressed in order that the work could be duplicated at a future time. The project manager was receptive to speaking engagements such as classroom presentations.

The highlight of the information transfer component of the study was the formal presentation of the results of the project at the Provincial conference of the New Brunswick Home Economic Association in Caraquet, New Brunswick. A detailed discussion followed the presentation in which much valuable information was exchanged. A copy of this program is also appended.

PROJECT COST ACCOUNTING

The total cost of this project was $12,235. Sixty-five per cent of this cost was received from the federal Department of Energy, Mines and Resources and the New Brunswick Energy Secretariat. The remaining portion was the responsibility of the project manager.

COST ANALYSIS

(i) Heat Available From System

The capital costs of changing the detailing of the construction of the building, in order to improve its thermal performance, have been estimated. Only the costs associated with modifying the building to passive solar collection have been considered.

The following method enables one to rapidly determine how long a potential investment will take to pay for itself: A graph (Figure 8) was derived from the following formula: (available in "Solar Energy for Existing Homes").

$$S = R \frac{(1 + k)\ (1 + k)^n - (1 + i)^n}{(1 + i)^n\ (1 + k) - (1 + i)}$$

Where S = initial capital expenditure

R = fuel cost saving in first year

k = fuel cost escalation

i = interest or general inflation rate

n = number of years

From the cost records, the list of additional material and labour input are:

Ventilation system	$1,520.00	
Collectors & Insulating Blinds	3,670.70	
Total		$5,190.70

Heat available from the passive solar heating is given below. This is only an estimation but should offer an insight into the potential of the system. One goal of the project is to attempt to measure what is indeed achieved by the system.

Daily Total Solar Energy

(Solar energy incident on a vertical surface)

	Hrs. of Bright Sunshine 80-81*	Energy** BTU/ft^2/day	Total
January/81	142.8	1368	42,408
February/81	113.8	1598	44,744
March/81	96.8	1544	47,864
April/81	185.7	1236	37,080
May/81	157.6	994	30,814
June	233.5	902	27,060
July	--	--	--
August	--	--	--
September/80	180.6	1482	44,460
October/80	133.2	1528	47,368
November/80	102.7	1338	40,140
December/80	94.3	1194	37,014
Total	1441.0		398,952 BTU

*Measured at Research Station, Fredericton, N. B.

**Taken from "Solar Energy for Existing Homes".

Recalling that the measured efficiency of the collectors - triple glazed - was 51.3% and assuming the cost of electrical energy at $0.045/kwh, the value of the heat gain by the system would be:

$$\frac{398,952 \times 0.513 \times 180 \times 0.045}{3413} = \$485.72$$

The actual heat gained is equivalent to 36,839,228 BTU. This value is comparable to the difference in heating requirements between the 79-80 and 80-81 heating seasons when considering the additional 300 ft^2 of heated space. Assuming annual interest rate on borrowed capital at 16% and fuel cost inflation rate to be 18%, the investment payback period can be determined from the attached graph. Investment dollars per year present saving is

$$\frac{5,190.70}{485.72} = 10.67$$

From the graph, payback period or break-even period is 9 1/2 years with the system.

Based on degree days below 18.0°C, the break-even period was also determined during the 79-80 and 80-81 heating periods.

Heat required per degree-day for 79-80

$$\frac{13610.0 \times 3413}{4555.3 \times 1200} = 8.5 \text{ BTU/DD/Ft}^2$$

Heat required per degree-day for 80-81

$$\frac{10500.0 \times 3413}{4705.4 \times 1500} = 5.0 \text{ BTU/DD/Ft}^2$$

Savings per year/ft^2 assuming 4800 degree-day

$$\frac{3.5 \times 0.045 \times 4800}{3413} = \$0.23 /ft^2$$

Cost of installation

$$\frac{5190.70}{1500} = \$3.46/ft^2 \text{ of house area}$$

Investment dollars per year present saving is

$$\frac{3.46}{0.23} = 15.0$$

From the graph, payback period is 12.8 years with this system.

(ii) Heat Transferred to Existing House

Heat removed with an average of a ten degree temperature gain in the ventilation air and with fan capacity of 500 cfm is determined by the following:

$$\frac{500 \times 0.23 \times 10 \times 60}{13.4} = 5149.3 \text{ BTU/hr.}$$

This capacity of ventilation combined with the heat sink of the material in the two rooms and transfer of heat by two opened doors assured uniform temperature in the rooms during the daylight hours.

The total heat transferred by the ventilation system can be calculated using the hours of bright sunshine and the capacity of heat transfer of the fan. This value determined for the ventilation is

4159.3 x 1441.0 = 7,420,141.3 BTU's/year.

This value can be at least doubled when considering the heat transferred to the existing house through the two opened doors.

CONCLUSIONS

An existing house was retrofitted with a 300 ft^2 addition which incorporated passive solar heat. The design proved very aesthetically pleasing as well as energy efficient. The following conclusions were ascertained:

(i) The passive solar addition contributed 36,839,228 BTU's/year to the heating of the entire house.

(ii) The payback period of the system was determined to be 9 1/2 years based on incoming radiation, and 12.8 years based on difference in electrical heating requirements.

(iii) The environment within the house was easily maintained at a comfortable level.

(iv) A technical pamphlet describing the project was prepared and circulated. Several formal and informal presentations explaining the project were made.

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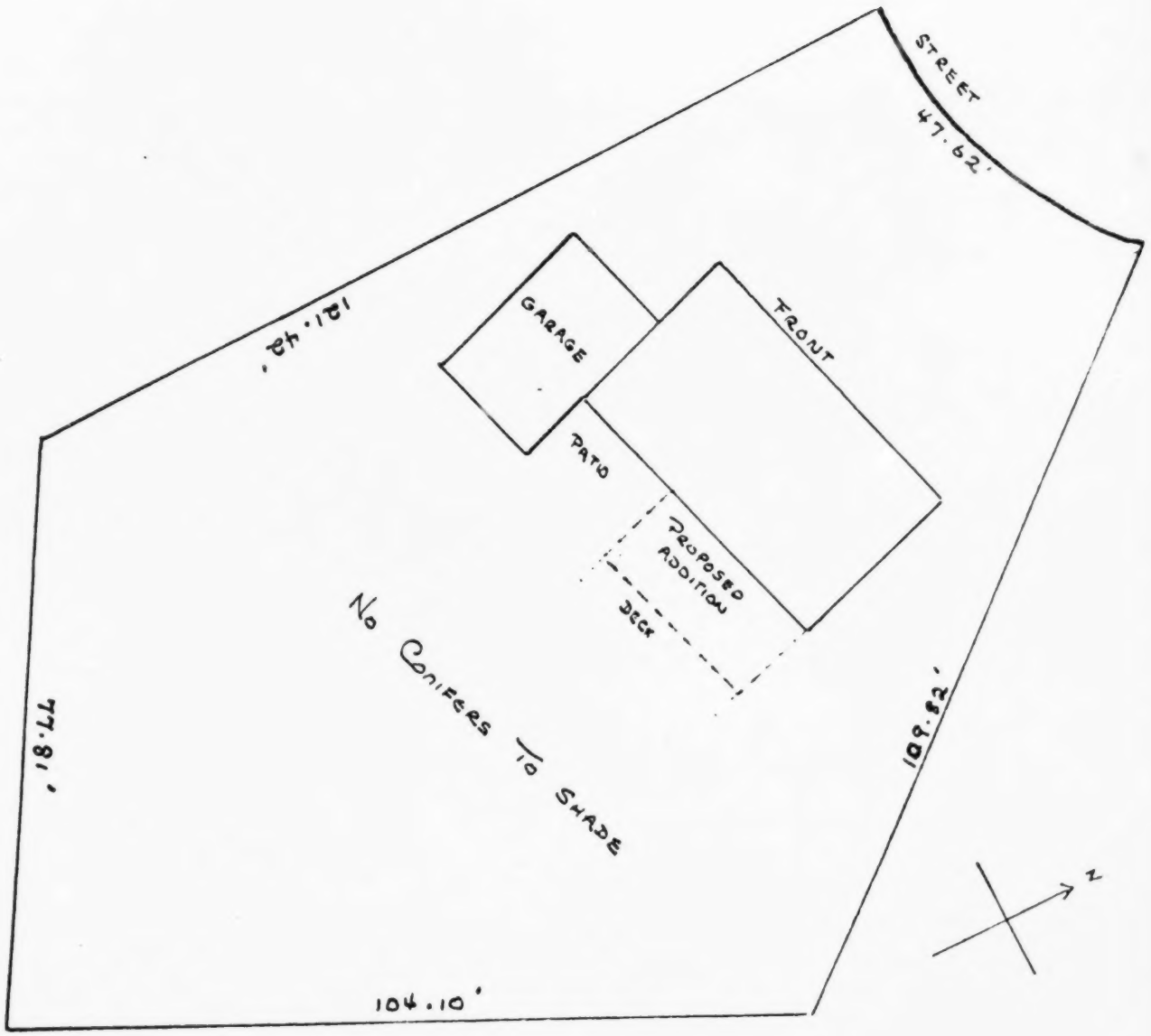

Figure 1 - House & Location on Lot

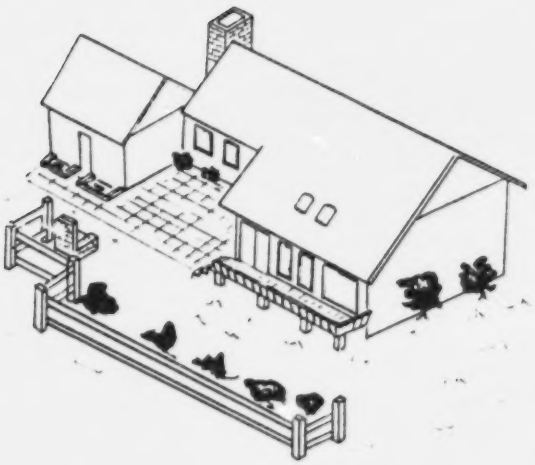

Figure 2 A - House - rear view

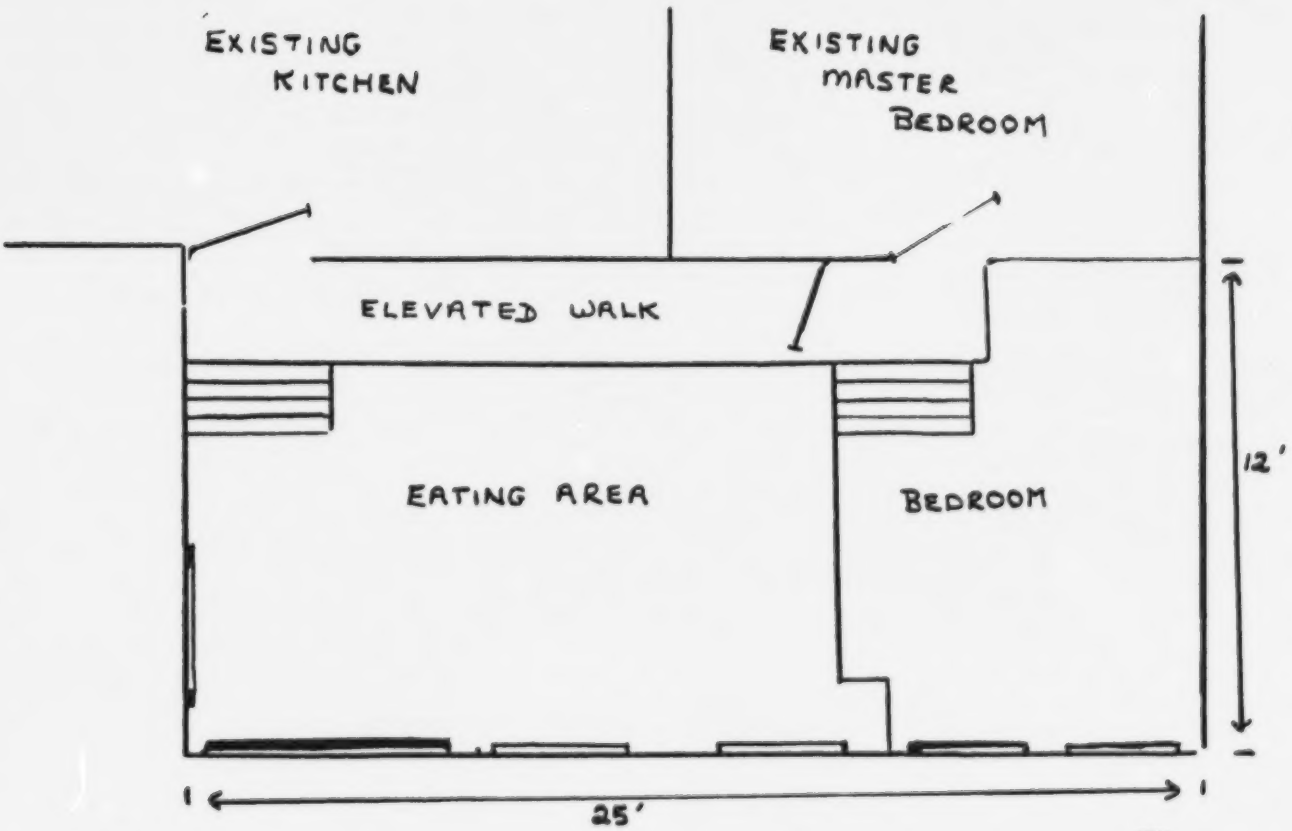

Figure 2 B - Layout of Addition

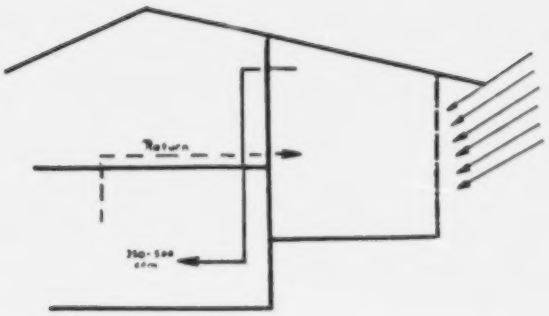

Figure 3 - Cross - Section of Solar System

Figure 5 - View of Solar Addition

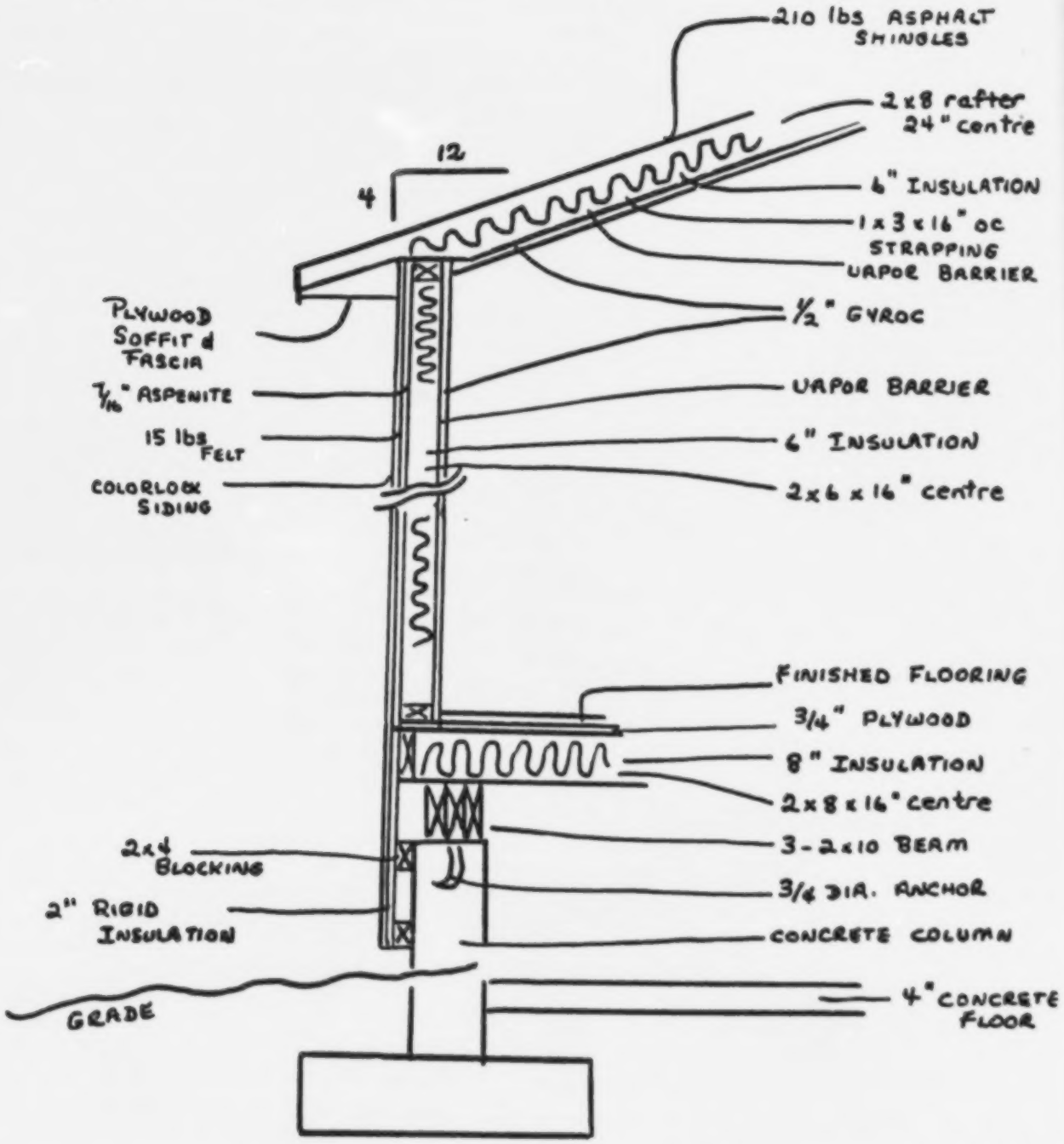

Figure 4 - Wall Section of Addition

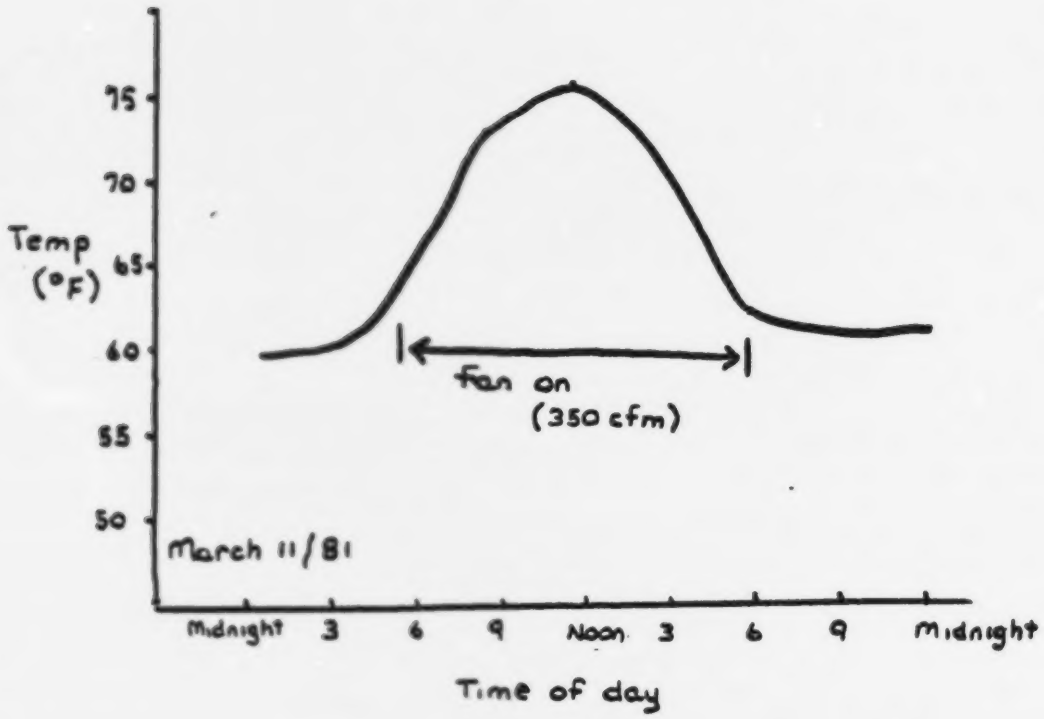

Figure 6 - Typical Temperature Profile

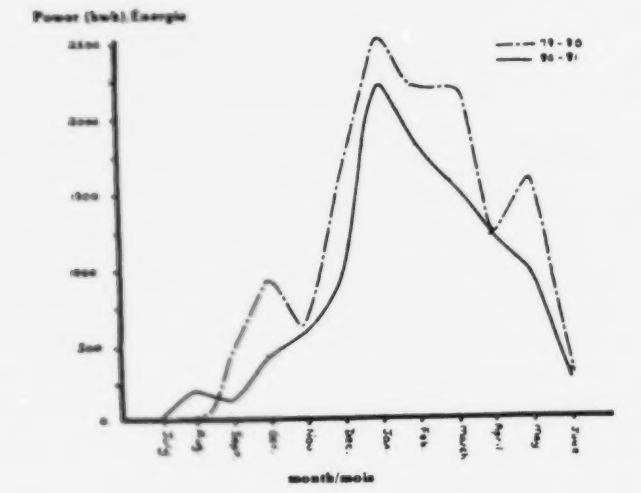

Figure 7 - Power Consumption Comparison Graph

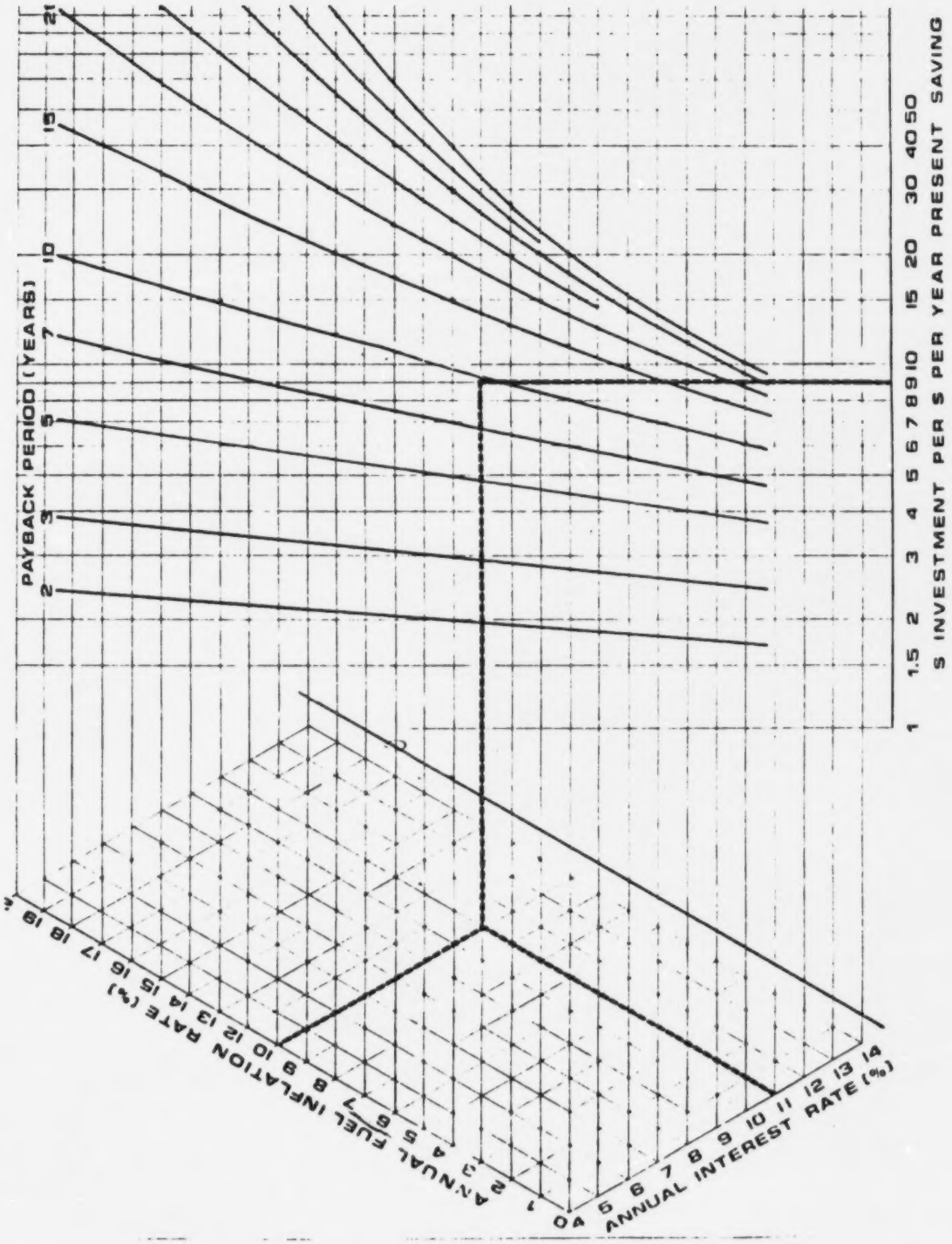
PAYBACK PERIOD (YEARS)
21
15
10
7
5
3
2
1 1.5 2 3 4 5 6 7 8 9 10 15 20 30 40 50
$ INVESTMENT PER $ PER YEAR PRESENT SAVING
ANNUAL FUEL INFLATION RATE (%)
0 4 5 6 7 8 9 10 11 12 13 14
ANNUAL INTEREST RATE (%)

Figure 8 - Solar Investment Payback